

# Measurement of the effect of temperature on some properties of liquid scintillator and PVC

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We have measured the thermal expansion of both liquid scintillator and PVC, the components proposed for use in constructing the NOvA detector. We have set limits on the possible effect of temperature on scintillator light output, and have also investigated the physical behavior of BC517L liquid scintillator at very low temperatures.

## Volume Expansion of BC517L liquid scintillator

Due to the large mass of liquid scintillator in the active cells of the detector, an estimate of the fractional volume expansion over a suitable temperature range is needed. Overflow tanks may be required to accommodate any overheating that may occur in the detector housing. We present here our measurement procedure and results for the mineral-oil based Bicron BC517-L scintillator and the PVC extrusion planned for use in the active element of the detector.

Our experimental setup involved a 125 ml Pyrex flask with a two-hole stopper, which accommodated a thermocouple and a 1 ml pipette. Pyrex was chosen for its low linear expansion coefficient ( $3.2 \times 10^{-6} / ^\circ\text{C}$ ). The flask was set in a heat bath and its temperature regulated accordingly. A volume reading was taken at every 0.5 degree over a temperature range 0-50 degrees Celsius. The calculated increase in volume of the Pyrex flask over the entire temperature range was only 0.06 ml, resulting in a very small correction to the data. An identical trial was conducted using baby oil (pure mineral oil) as a consistency check.

Some data are shown in Figure 1. We obtained average values for the volume expansion coefficient of  $(7.65 \pm 0.07) \times 10^{-4} / ^\circ\text{C}$  for the BC517L scintillator and  $(7.7 \pm 0.1) \times 10^{-4} / ^\circ\text{C}$  for the baby oil. Both of these are in good agreement with the accepted value for mineral oil:  $(7.6 \pm 0.1) \times 10^{-4} / ^\circ\text{C}$ .

## Linear Expansion of PVC

We used a Michelson interferometer to make this measurement. One arm of the interferometer was left empty, and the mirror on the second arm was mounted on a piece of PVC extrusion of known length. The entire apparatus was contained in an insulating box with holes allowing the passage of the laser light. The box was heated by placing a ceramic heater with a variable voltage supply inside, and cooled by evaporating liquid nitrogen inside. The temperature inside the box was kept uniform by the use of a small fan which circulated the enclosed air volume. A suitable beam collimator was used to provide the parallel rays needed to observe the interference effect. Cycles of constructive and destructive interference were observed in the ring pattern over a temperature range 10-50 degrees Celsius, and a temperature reading was taken after every five cycles had passed.

The measured linear expansion coefficient for the PVC extrusion was  $(6.7 \pm 0.2) \times 10^{-5} / ^\circ\text{C}$ , corresponding to a volume coefficient of expansion of  $(2.00 \pm 0.06) \times 10^{-4} / ^\circ\text{C}$

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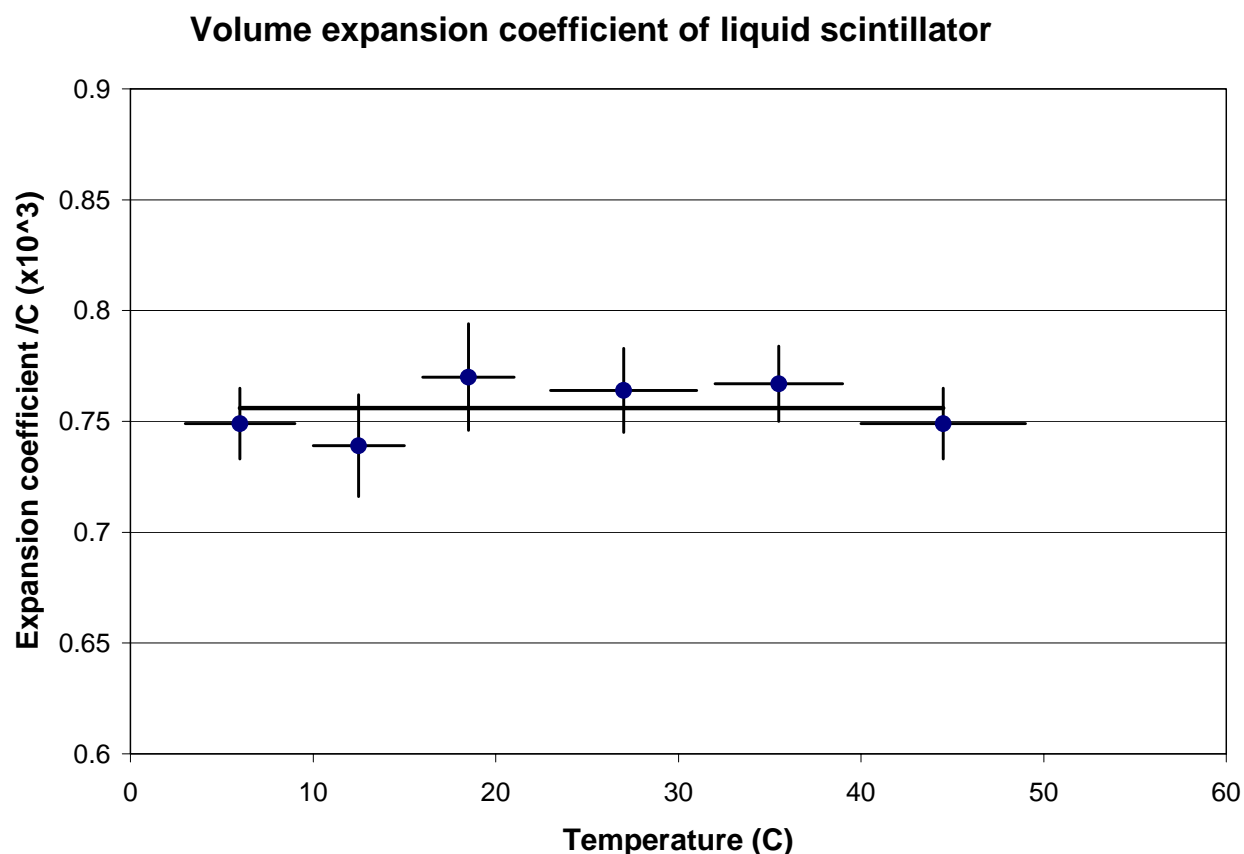


Figure 1. Volume expansion coefficient of BC517L as a function of temperature.

### Scintillator expansion in the NOvA detector

In one version of the totally active detector, the volume of scintillator in a single 32-cell extrusion is  $1.07\text{m}^3$  ( $17.5\text{m} \times 4.9\text{cm} \times 3.9\text{cm}$ ) and so there must be accommodation for an overflow of  $820\text{cm}^3/\text{°C}$ . The preliminary manifold design described in the proposal has already taken this into account.

The 17.5m extrusions will expand in length by  $0.12\text{ cm}/\text{°C}$  and the 90 m long detector by  $0.60\text{ cm}/\text{°C}$ .

### Temperature Effects on Light Output

To gain an understanding of the liquid scintillator's response to temperature changes, we exposed samples to large temperature shifts and measured the light output as the sample returned to room temperature. We were most concerned with the extremes that the liquid might be exposed to during winter transportation in northern Minnesota or during a loss of temperature control in the detector housing on a hot summer day.

A two-inch diameter glass jar of liquid scintillator was used in all of our trials, along with a Burle 8575 photomultiplier tube of the same diameter. One temperature probe was passed through the lid of the

jar, while another probe monitored the temperature of the face of the PMT. A  $^{137}\text{Cs}$   $\gamma$ -source was used to illuminate the jar of scintillator, while the whole setup was contained in a light-tight box. Heating was achieved using an industrial heat gun. Readout of the PMT was done on a qVt multichannel analyzer. The channel position of the familiar Compton edge of the recoil electron energy was used as the measure of light output of the sample.

These measurements proved quite difficult, since the effects were small and the experiment was susceptible to small drifts in qVt gain and, especially, variations in PMT gain with temperature. These systematic PMT effects constrained the ultimate precision of the measurement. We report a maximum decrease in scintillator light output of 1%/°C. This is an upper bound, and it is our conclusion that a more stable light-collection device should be used if future inquiry is desired into this effect.

Extreme temperatures should be avoided during operation. Temperatures approaching the flash point of pseudocumene (48°C) should especially be avoided. Our data show that, after heating to temperatures beyond this point, light output dropped significantly and that some of the pseudocumene had likely vaporized and escaped from our container. This may be a source of a decrease in light output on a time scale of years, as the pseudocumene may slowly evaporate even at room temperature.

## **Behavior at very low temperatures**

Temperatures below -10°C caused a clouding effect and rendered the liquid opaque. The scintillator became “slushy”. An interesting effect was observed at temperatures below -30°C: balls with diameters ranging up to a centimeter were observed to solidify out of the scintillator. These balls did not dissolve when the scintillator was returned to room temperature. They were observed to congeal with each other, but would not mix with the rest of the solution.

A search on the web indicates that these are well-known properties of oils at low temperatures. All oils contain paraffin waxes and these crystallize at very low temperatures. The temperature at which this begins to occur is called the “cloud point”. Eventually, at lower temperature, flow can be totally inhibited; this is the “pour point”. For example, diesel fuel has a pour point of only 5°F and additives are required to reduce this to about -20°F. Oil can be pumped at temperatures satisfactorily as long as temperatures are kept about 20°F above the pour point.

These effects clearly have strong implications for winter delivery of liquid scintillator via tanker-trailer or tank car. The scintillator must be kept above its pour point at all times during transportation and this must be specified in any purchase agreement. A mineral oil supplier has suggested that jacketed steam cars are often used in such situations. Electrically heated cars are also available. (See [www.utlx.com](http://www.utlx.com), for example).

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